

Searches for BSM physics involving top quarks and other BSM physics searches with ATLAS

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14.04.2011



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BMBF-Forschungsschwerpunkt
ATLAS Experiment

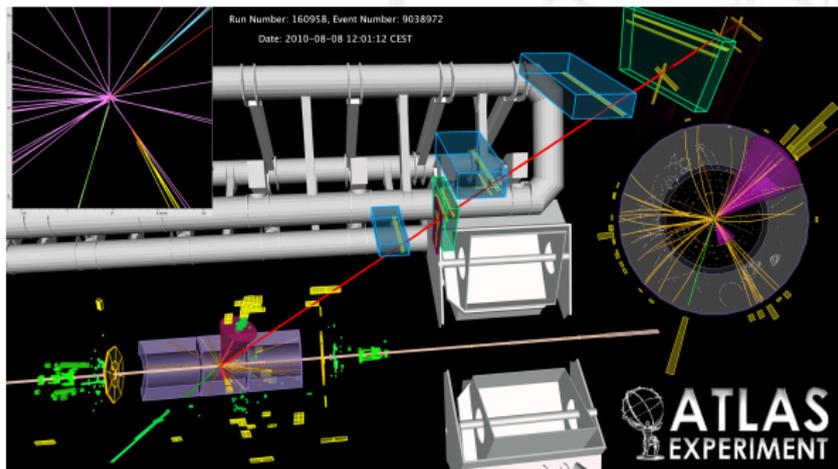
FSP 101

Physics on the TeV-scale at the Large Hadron Collider

ATLAS

Searches for New Physics

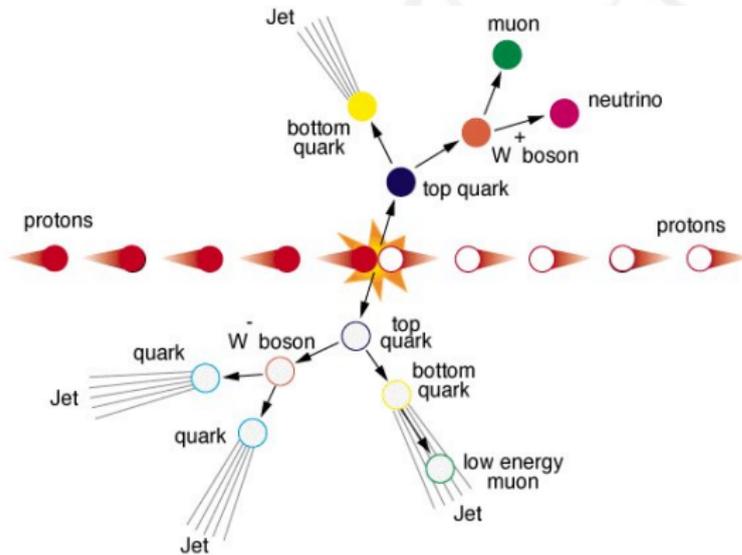
- a lot of BSM models \rightarrow answer open questions in the Standard Model
- new physics will manifest in similar event topology
 \Rightarrow one final state can be used to search/constrain several models
- searches at ATLAS with 2010 data, $\mathcal{L}_{\text{int}} \approx 35 - 40 \text{ pb}^{-1}$:



event signatures
treated in this talk:

- lepton + E_T^{miss} + jets
- di-jet
- lepton + E_T^{miss}
- di-lepton
- di-lepton + (di-)jets
- di-photon

$t\bar{t}$ semileptonic decays



- anomalous missing E_T
- Wtb vertex & anomalous couplings
- FCNC top production/decay

Anomalous Missing E_T in $t\bar{t}$ Events

- pair-produced exotic top partner T :

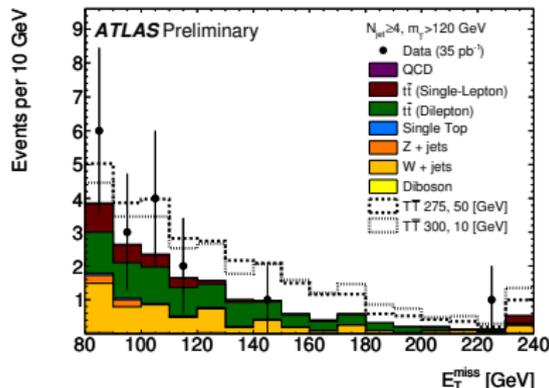


- quark-like quantum numbers
- decays to top and stable, neutral scalar A_0
- several models predicting exotic top partner T : dark matter models, SUSY, little Higgs ...
- final state identical to SM $t\bar{t}$ with a large amount of E_T^{miss}
 - this talk: semileptonic final state
- simple cut-and-count analysis with $E_T^{\text{miss}} > 80$ GeV and $m_{W_T} > 120$ GeV cuts

Results of the Search for Anomalous Missing E_T

- expected bgd and observed yields:

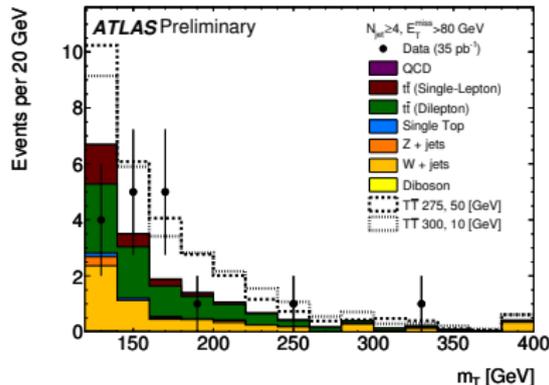
source	yield
single-lepton $t\bar{t}/W$	8.4 ± 1.6
di-lepton $t\bar{t}$	7.6 ± 2.0
Z jets	0.4 ± 0.1
di-bosons	$0.2 \pm <0.1$
single top	0.4 ± 0.1
QCD	0.2 ± 0.6
total background	17.2 ± 2.6
data	17



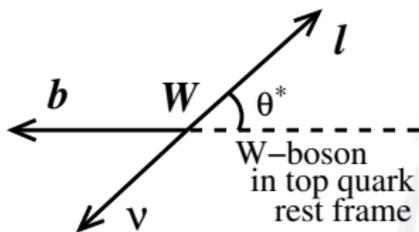
- expected yields for 2 benchmarks (E.Berger, Q.-H.Cao, arXiv:09093555[hep-ph]):

signal	yield
$m(T) = 275$ GeV $m(A_0) = 50$ GeV	12.4 ± 3.1
$m(T) = 300$ GeV $m(A_0) = 10$ GeV	11.7 ± 3.0

⇒ both benchmarks
exclusion at 95% C.L.



W-boson Polarisation in Top Quark Decays

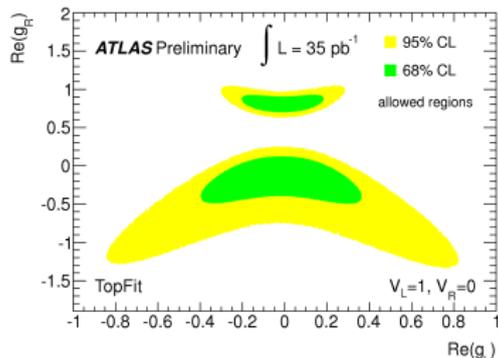
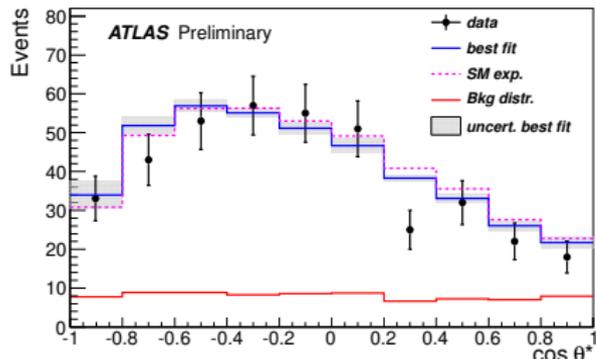


- Wtb vertex \rightarrow hints to new physics
- measure the fraction of longitudinal, right-handed and left-handed W -bosons \rightarrow consistent with SM expectation

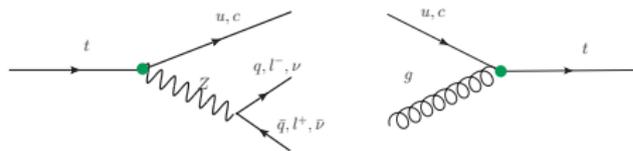
- limits on 'anomalous' couplings $g_L, g_R \rightarrow$ effective Lagrangian

$$\mathcal{L}_{Wtb} = -\frac{g}{\sqrt{2}} \bar{b} \gamma^\mu (V_L P_L + V_R P_R) t W_\mu^- - \frac{g}{\sqrt{2}} \bar{b} \frac{i\sigma^{\mu\nu} q_\nu}{M_W} (g_L P_L + g_R P_R) t W_\mu^- + h.c.$$

\rightarrow model-independent, new physics above EWSB scale



Flavour Changing Neutral Currents



- $t \rightarrow qZ$: $3\ell + 2 \text{ jets} + E_T^{\text{miss}}$

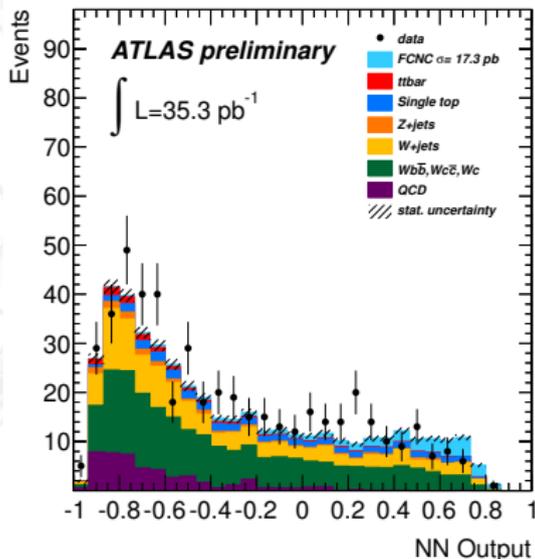
	e	μ
exp bgd	0.23 ± 0.11	0.17 ± 0.08
data	0	1

→ observed upper limit on
 $\text{BR}(t \rightarrow qZ) = 17\% \text{ @ } 95\% \text{ C.L.}$

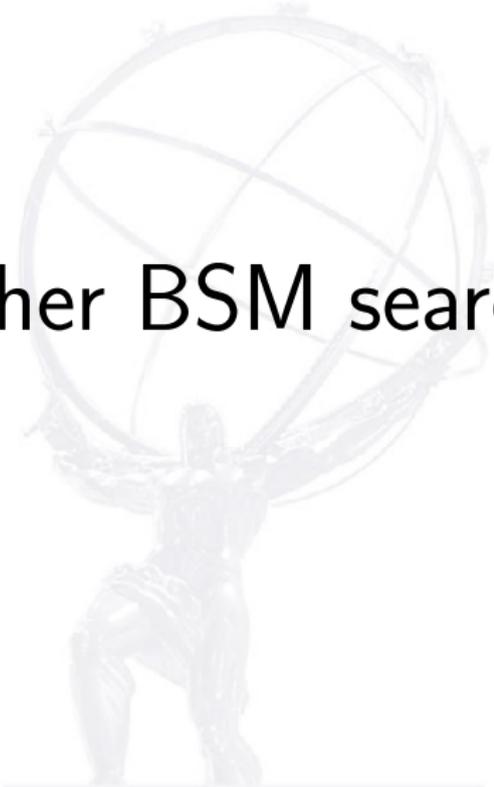
- $gq \rightarrow t$: $\ell + 1 \text{ b-jet} + E_T^{\text{miss}}$

- use NN NeuroBayes[®] to separate signal & background

- 13 variables: $p_{T,W}, \Delta R(\ell, b), \ell$ charge, $m_t, \Delta\varphi(W, b), \dots$



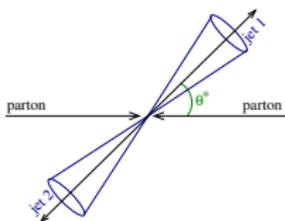
- NN output → Bayesian limit
- observed upper limit on
 $\sigma(gq \rightarrow t) = 17.3 \text{ pb @ } 95\% \text{ C.L.}$



other BSM searches

Di-Jet Mass and Angular Distributions

- consider events with two high energy jets recoiling back-to-back



$$y^* = \frac{1}{2}(y_1 - y_2)$$

$$= \frac{1}{2} \ln \frac{1 + |\cos\theta^*|}{1 - |\cos\theta^*|}$$

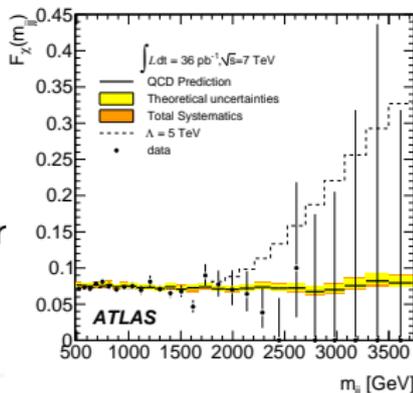
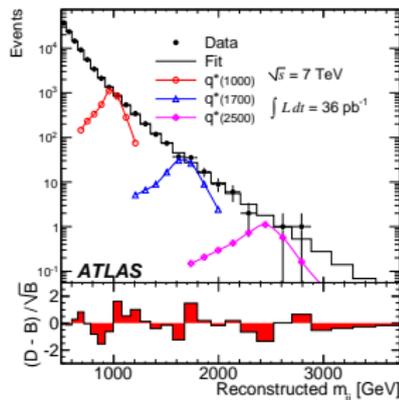
$$F_\chi = \frac{N_{\text{events}}(|y^*| < 0.6)}{N_{\text{events}}(|y^*| < 1.7)}$$

→ bump search: invariant mass m_{jj}

→ non-resonance: angular dist., e.g. $F_\chi(m_{jj})$

- no evidence for a bump in the m_{jj} distribution, no any deviation in the angular dist. (χ^2 -test, p-value 0.88)

⇒ exclusion limits



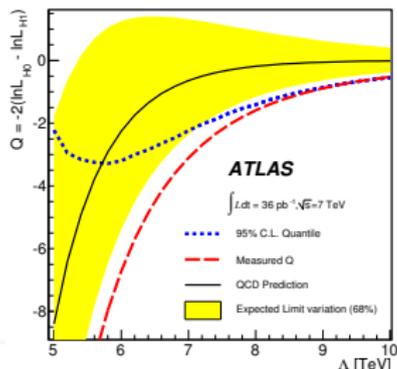
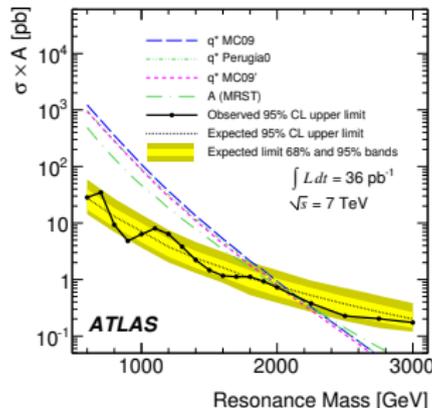
Di-Jet Exclusion Limits

observable	M _X , TeV upper limit @ 95% C.L.	
	expected	observed
excited quark q*		
m _{jj}	2.07	2.15
F _χ (m _{jj})	2.12	2.64
Randall-Meade quantum black hole for n=6		
m _{jj}	3.64	3.67
F _χ (m _{jj})	3.49	3.78
axigluon		
m _{jj}	2.01	2.10

contact interaction Λ

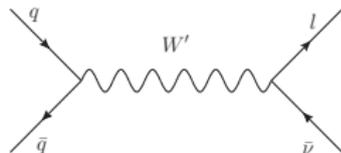
F_χ(m_{jj}) **5.72** **9.51(6.7)***

- * 9.51 TeV: CL_{s+b}, within 2σ,
6.7 TeV: Bayesian as a check
- excited quark: M > 870 GeV
(CDF, Phys.Rev. D79 112002, 2009)
- axigluon: M > 1250 GeV
(CDF, Phys.Rev. D79 112002, 2009)
- contact interaction: $\Lambda > 2.9$ TeV
(DØ, Phys.Rev.Lett. 103:191803, 2009)

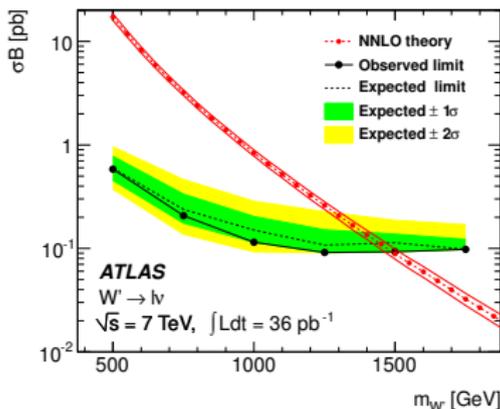
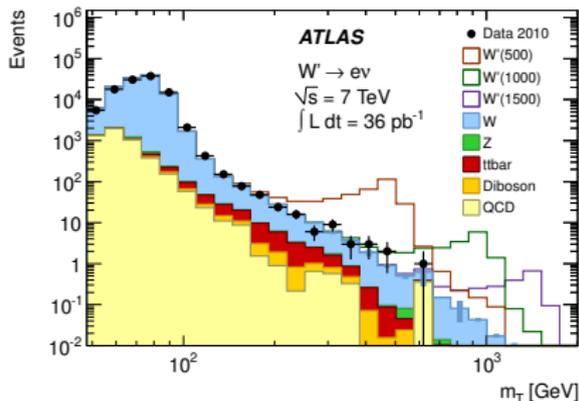


Searches in Lepton + E_T^{miss} Final States

- additional heavy gauge bosons:
 - $W' \rightarrow l\nu$ same couplings like W -boson (SSM)
 - $W^* \rightarrow l\nu$ excited boson with chiral couplings



→ observable $m_T = \sqrt{2p_T E_T^{\text{miss}} (1 - \cos\varphi_{l\nu})}$



→ $M_{W'} > 1490 \text{ GeV} @ 95\% \text{ C.L.}$

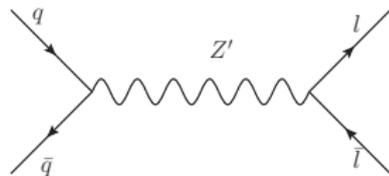
→ $M_{W^*} > 1320 \text{ GeV} @ 95\% \text{ C.L.}$

- Tevatron: $M_{W'} > 1100 \text{ GeV} @ 95\% \text{ C.L.}$
(CDF note 10303, 2010)

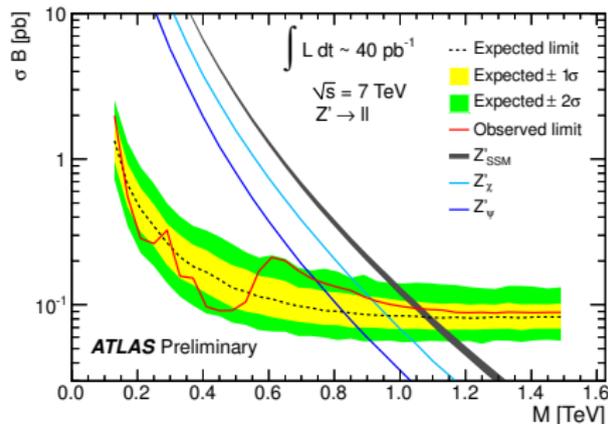
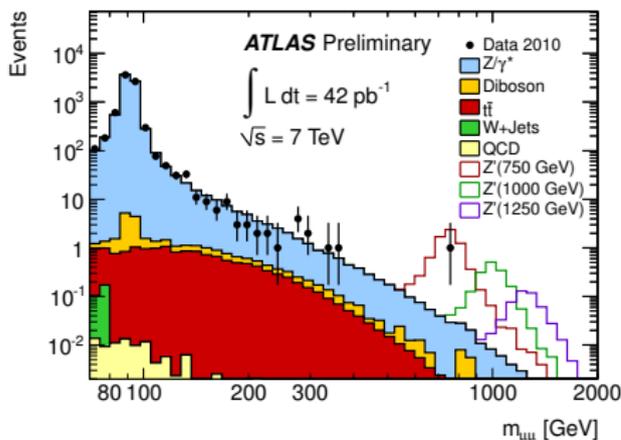
Searches in Di-Lepton Final States

- neutral heavy gauge bosons:

Z' in sequential SM, Z^* , Z' 's in GUT with E_6 group (Phys. Rev. D34, 1530)



→ observable: invariant mass m_{ee} , $m_{\mu\mu}$



→ $M_{Z'_{SSM}} > 1048 \text{ GeV} @ 95\% \text{ C.L.}$

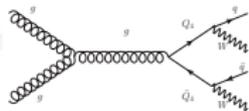
→ $M_{Z^*} > 1236 \text{ GeV} @ 95\% \text{ C.L.}$

E_6	Z'_ψ	Z'_N	Z'_η	Z'_1	Z'_S	Z'_χ
m, GeV	738	763	771	842	871	900

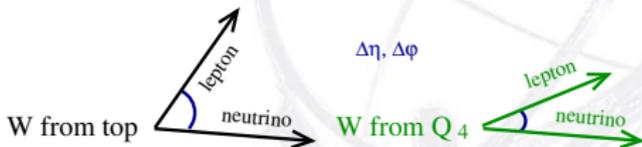
- Tevatron: $M_{Z'_{SSM}} > 1071 \text{ GeV}$
(CDF, arXiv:1101.4578,2011)

Searches with Di-Lepton + Jets

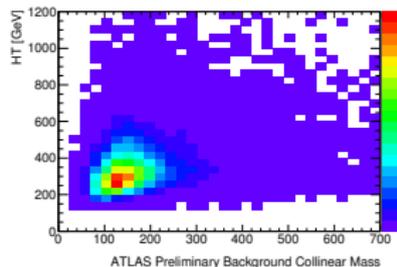
- 4th generation chiral quarks
- first search in ll -channel
- discriminant: $M_{\text{collinear}}$ vs H_T



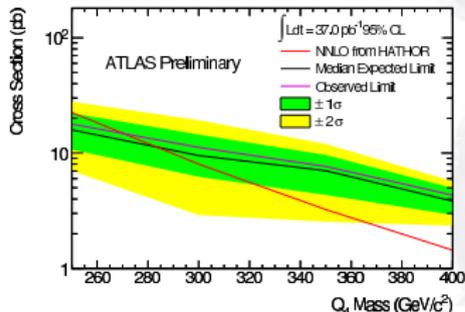
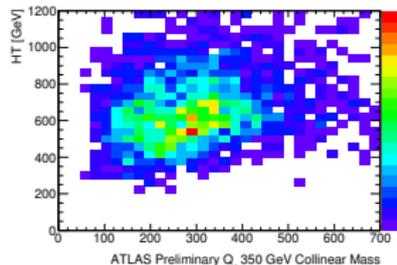
- $H_T = E_T(\ell^+) + E_T(\ell^-) + E_T(q_1) + E_T(q_2) + E_T^{\text{miss}}$
- find $\Delta\eta, \Delta\phi$ to minimise difference in $M_{\text{collinear}}$ for both Q_4



background



signal



- $M_{Q_4} > 270 \text{ GeV}$
@ 95% C.L.

- Tevatron:

$$M_{u_4} > 356 \text{ GeV},$$

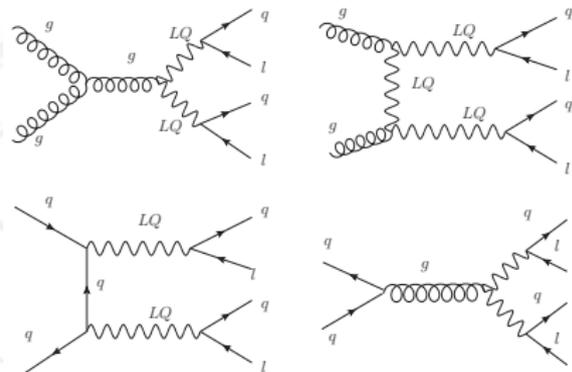
$$M_{d_4} > 372 \text{ GeV}$$

CDF, arXiv:1101.5728

$\Rightarrow m_{Q_4}$ - dependent
triangular cuts
($H_T, M_{\text{collinear}}$)

Search with Di-Lepton + Di-Jets

- **leptoquark** carries lepton & quark quantum numbers
- β = branching fraction of a leptoquark to a charged lepton
 $\rightarrow lljj, lvjj$ final states
- **observables:**



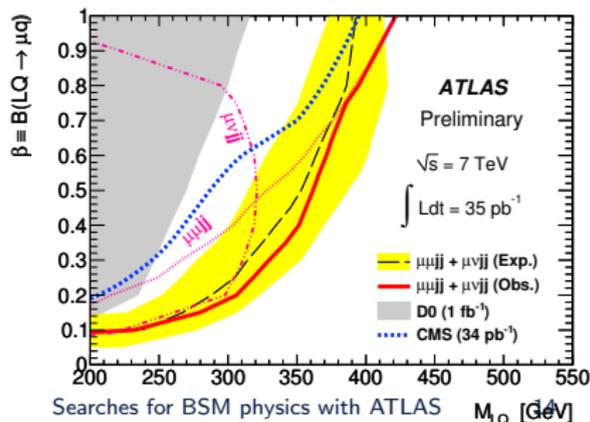
- \rightarrow leptoquark (trans.) inv. mass
- $\rightarrow S_T^v = p_T^{\ell_1} + E_T^{\text{miss}} + p_T^{j_1} + p_T^{j_2}$
- $\rightarrow S_T^\ell = p_T^{\ell_1} + p_T^{\ell_2} + p_T^{j_1} + p_T^{j_2}$

- upper limits @ 95% C.L.:

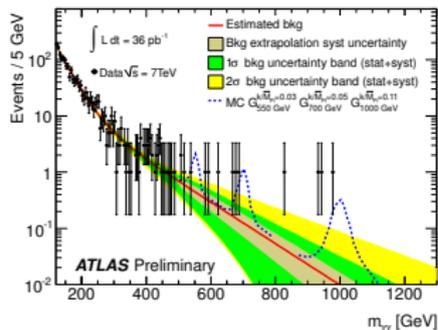
β	$M_{1.\text{gen}}$	$M_{2.\text{gen}}$
0.5	319 GeV	362 GeV
1.0	376 GeV	422 GeV

- DØ: Phys Lett B 671 224, 2009

2nd generation



Searches with Di-Photons



- Randall-Sundrum graviton: $G \rightarrow \gamma\gamma$

- TeV scale \rightarrow Plank scale $\Lambda_\pi = \frac{1}{\sqrt{8\pi}} M_{\text{Pl}} \exp(k\pi r_c)$

- k : curvature, r_c : radius of extra dimensions

\Rightarrow massive graviton excitations, Kaluza-Klein (KK) tower

$\rightarrow M_G > 545 \text{ GeV} (k/\bar{M}_{\text{Pl}} = 0.02) @ 95\% \text{ C.L.}$

$\rightarrow M_G > 920 \text{ GeV} (k/\bar{M}_{\text{Pl}} = 0.1) @ 95\% \text{ C.L.}$

- universal extra dimensions (UED):

- for each SM particle exists a KK tower

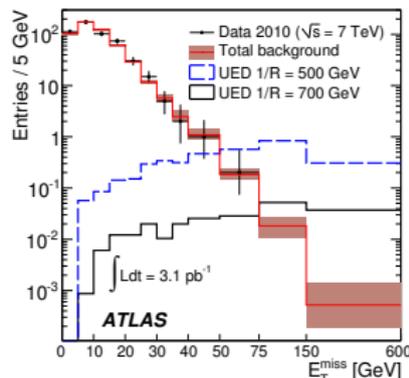
- state masses are separated by $\approx 1/R$

- lightest particle $\gamma^* \rightarrow \gamma + G$ (2 times)

\Rightarrow final state: $\gamma\gamma + E_T^{\text{miss}} + X$

$\rightarrow 1/R > 728 \text{ GeV} @ 95\% \text{ C.L.}$

- Tevatron: $1/R > 477 \text{ GeV} (D\emptyset, \text{PRL } 105, 221802, 2010)$



Conclusions

- first results with $\sim 35 \text{ pb}^{-1}$ 2010 data @ $\sqrt{s} = 7 \text{ TeV}$
→ one final state used to constrain several models
- with very little data, already able to push the reach to the TeV scale, to surpass Tevatron or to set world's best limits:
 - excited quarks, QBHs, axigluons, contact interaction Λ
 - W', W^*
 - 1st, 2nd generation leptoquarks
 - universal extra dimensions

2011 → start to explore new territories